

"Method for compressing/decompressing video information"

FIELD OF THE INVENTION

The present invention relates to a method for compressing/decompressing video information, and to corresponding compressing and decompressing devices. It also relates to a computer program product for carrying out said method, to compressed data obtained by
5 implementation of said method, and to devices for compressing and decompressing video information.

BACKGROUND OF THE INVENTION

The current standards belong to the MPEG family like MPEG-1, MPEG-2 and MPEG-4 (see for instance MPEG-4 Visual coding standard ISO/IEC 14496-2, document
10 available at ISO, referred here under the MPEG-4 document number w3056) and to the ITU H.26X family like H.261, H.263 and extensions, and H.264.

Most video coding standards take advantage of the fact that there are some redundancies between subsequent frames of a video sequence. In most video compression algorithms, each frame is subdivided into segments which can be regular square blocks, as in
15 MPEG-4, or square or rectangular blocks as in H.264. When decompressing the compressed data, each segment of a following frame is obtained by calculation of a prediction, based on a corresponding segment of a previous frame by using motion information generally called motion vector, and correction or residual information generally called residual image defining the differences between the segment and its prediction and more generally between
20 the frame and its prediction. The compression standards provide a way of encoding the motion information and the correction information for retrieving a following frame based on a previous known frame.

Mainly, two approaches are used by the compression standards. A first approach is named the backward approach. It is implemented in MPEG and ITU H.26X standards. In the
25 backward approach, for each segment of a following frame, the compression method tries to find the segment of the previous frame that is the closest to it or at least less far from it. This may cause problems for segments that appear in the following frame and not in the previous frame. Still, for any segment that is present in both the previous and the following frames, this system gives the best prediction, for a given motion model, providing a full search of the
30 motion parameters is done, that is to say that any possible parameters are considered. The problem with the backward approach is that, in many cases, the used frame segmentation

does not coincide with the frame segmentation into "real" objects that may have different overall motions.

The second approach is named the forward approach. This approach is disclosed for example in WO-00/64167. It uses a segmentation based coding scheme using "real" objects
 5 of the frame. In the forward approach, for each segment of a previous frame, which is considered as an independent object, the best match is searched in the following frame, that is to say the method tries to find what the object became between the two frames. The segments of the following frames that are predicted are not optimally predicted with regard to the considered motion model. It is not sure to have the best possible prediction of the following
 10 frame from the previous frame, even with full search motion estimation. Indeed the optimisation is performed regarding what one has, i.e. the previous frames, and not regarding what one wants to have, i.e. the new frame.

SUMMARY OF THE INVENTION

15 It is therefore the object of the invention to provide a video compression method - and an associated decompression method - that enables to optimise the segmentation used for the prediction of a following frame based on a known previous frame.

To this end, the invention relates to a method for compressing video information in a video sequence (I_t, I_{t+1}) comprising the steps of :

- 20 . considering in said sequence a first video frame (B_t) containing image data ;
- . segmenting said first video frame (B_t) into segments ($S_{t,i}$) ;
- . for each segment ($S_{t,i}$) of the first video frame (B_t) :
 - searching, in a second video frame (I_{t+1}) following the first video frame (B_t) in the video sequence, a corresponding predicted segment ($S_{t+1,i}^{p,forward}$) which matches with the
 - 25 segment ($S_{t,i}$) of the first video frame (B_t) according to a predetermined similarity measure ;
 - calculating a raw set of motion parameters ($M_{t,i}^p$) describing the motion between the segment ($S_{t,i}$) of the first video frame (B_t) and the corresponding predicted segment ($S_{t+1,i}^{p,forward}$) of said second video frame (I_{t+1}) ; and
 - . for each corresponding predicted segment ($S_{t+1,i}^{p,forward}$) of the second video frame
 - 30 (I_{t+1}):

- searching, in the first video frame (B_t), a corresponding segment ($S_{t,i}^{p,backward}$) that matches with the predicted segment ($S_{t+1,i}^{p,forward}$) of the second video frame (I_{t+1}) according to a predetermined similarity measure ;

- calculating a best set of motion parameters ($M_{t,i}^p + \Delta M_{t,i}^p$) describing the motion between the corresponding segment ($S_{t,i}^{p,backward}$) of the first video frame (B_t) and the predicted segment ($S_{t+1,i}^{p,forward}$) of the second video frame (I_{t+1}), said best set of motion parameters consisting in the raw set of motion parameters ($M_{t,i}^p$) corrected by a motion parameters correction ($\Delta M_{t,i}^p$).

As seen later in the description, such a method has the advantage to provide a segmentation of the following frame which is optimised before applying a backward approach to determine the best set of motion parameters.

Additional features are recited in the sub-claims 2 to 8.

Another object of the invention is to propose a method for decompressing video information in a video sequence (I_t, I_{t+1}) comprising :

- . considering a first video frame (B_t) containing image data;
- . segmenting said first video frame (B_t) into segments ($S_{t,i}$);
- . for each segment ($S_{t,i}$) of the first video frame (B_t), defining a projected segment ($S_{t+1,i}^p$) by applying to the segment ($S_{t,i}$) of the first video frame (B_t), a raw set of motion parameters ($M_{t,i}^p$) describing the motion between the segment ($S_{t,i}$) of the first video frame (B_t) and the corresponding projected segment ($S_{t+1,i}^p$) and
- . for each corresponding projected segment ($S_{t+1,i}^p$):
- finding in the first video frame (B_t) a corresponding improved segment ($S_{t,i}^b$) using both the raw set of motion parameters ($M_{t,i}^p$) and a motion parameters correction ($\Delta M_{t,i}^p$), the corresponding improved segment ($S_{t,i}^b$) being the segment of the first video frame (B_t) that would be projected on the corresponding projected segment ($S_{t+1,i}^p$) by applying to it the raw set of motion parameters ($M_{t,i}^p$) corrected by the motion parameters correction ($\Delta M_{t,i}^p$) ; and

- defining a corrected projected segment ($S_{t+1,i}^{p,o,c}$) by applying the raw set of motion parameters ($M_{t,i}^p$) corrected by the motion parameters correction ($\Delta M_{t,i}^p$) to the corresponding improved segment ($S_{t,i}^b$).

5 It also concerns a computer program product for a data processing unit, comprising a set of instructions, which, when loaded into said data processing unit, causes the data processing unit to carry out the compressing method previously mentioned.

In addition, the invention also relates to a device for compressing video information in a video sequence (I_t, I_{t+1}) comprising :

- 10 - means for segmenting the first video frame (B_t) containing image data into segments ($S_{t,i}$);
- means for searching, in a second video frame (I_{t+1}) following the first video frame (B_t) in the video sequence, a corresponding predicted segment ($S_{t+1,i}^{p,forward}$) which matches with the segment ($S_{t,i}$) of the first video frame (B_t) according to a predetermined similarity measure, for each segment ($S_{t,i}$) of the first video frame (B_t) ;
- 15 - means for calculating a raw set of motion parameters ($M_{t,i}^p$) describing the motion between the segment ($S_{t,i}$) of the first video frame (B_t) and the corresponding predicted segment ($S_{t+1,i}^{p,forward}$) of the second video frame (I_{t+1}), for each segment ($S_{t,i}$) of the first video frame (B_t) ;
- means for searching, in the first video frame (B_t), a corresponding segment ($S_{t,i}^{p,backward}$) that matches with the predicted segment ($S_{t+1,i}^{p,forward}$) of the second video frame (I_{t+1}) according to a predetermined similarity measure, for each corresponding predicted segment ($S_{t+1,i}^{p,forward}$) of the second video frame (I_{t+1}) ;
- 20 - means for calculating a best set of motion parameters ($M_{t,i}^p + \Delta M_{t,i}^p$) describing the motion between the corresponding segment ($S_{t,i}^{p,backward}$) of the first video frame (B_t) and the predicted segment ($S_{t+1,i}^{p,forward}$) of the second video frame (I_{t+1}), said best set of motion parameters consisting in the raw set of motion parameters ($M_{t,i}^p$) corrected by a motion parameter correction ($\Delta M_{t,i}^p$), for each corresponding predicted segment ($S_{t+1,i}^{p,forward}$) of the second video frame (I_{t+1}). The invention still relates to a device for decompressing video information in a video sequence (I_t, I_{t+1}) comprising :
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- means for segmenting said first video frame (B_t) containing image data into segments ($S_{t,i}$);

- means for defining a projected segment ($S_{t+1,i}^p$) for each segment ($S_{t,i}$) of the first video frame (B_t), by applying to the segment ($S_{t,i}$) of the first video frame (B_t), a raw set of motion parameters ($M_{t,i}^p$) describing the motion between the segment ($S_{t,i}$) of the first video frame (B_t) and the corresponding projected segment ($S_{t+1,i}^p$);

- means for finding, in the first video frame (B_t), a corresponding improved segment ($S_{t,i}^b$) using both the raw set of motion parameters ($M_{t,i}^p$) and a motion parameters correction ($\Delta M_{t,i}^p$), the corresponding improved segment ($S_{t,i}^b$) being the segment of B_t that would be projected on the corresponding projected segment ($S_{t+1,i}^p$) by applying to it the raw set of motion parameters ($M_{t,i}^p$) corrected by the motion parameters correction ($\Delta M_{t,i}^p$), for each corresponding projected segment ($S_{t+1,i}^p$); and

- means for defining a corrected projected segment ($S_{t+1,i}^{p,o,c}$) by applying the raw set of motion parameters ($M_{t,i}^p$) corrected by the motion parameters correction ($\Delta M_{t,i}^p$) to the corresponding improved segment ($S_{t,i}^b$), for each corresponding projected segment ($S_{t+1,i}^p$).. It also concerns compressed data corresponding to a video sequence as obtained by the previously mentioned compressing method.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be now described, by way of example, with reference to the accompanying drawings in which :

- Figure 1 is a schematic view of a typical processing chain for a video sequence made of successive frames ;

- Figure 2 is a flow chart showing the video compression algorithm of the method for encoding a sequence of frames according to the invention ;

- Figure 3 is a schematic view of a processed frame at successive steps during the compression operation ;

- Figure 4 is a flow chart showing the video decompression algorithm of the method for decoding the compressed data corresponding to the compression method of a sequence of frames according to the invention ; and

- Figure 5 is a schematic view of a processed frame at successive steps during the decompression operation.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 shows a typical processing chain for a video sequence made of successive frames, each frame containing image data. This chain includes an encoder 12 adapted to receive a sequence of frames. These frames, provided for example by a digital camera, are arrays of pixels, each pixel being characterized by color parameters, which can be chrominance and luminance or Red, Green and Blue values for example. In the following, the t^{th} frame of an input sequence is denoted I_t .

The encoder 12 is adapted to implement a video compression method according to the invention and to output encoded data that are compressed. The compression method takes advantage of the fact that there are some redundancies between subsequent frames of the video sequence. The encoded data are then stored in a support like a tape or are transmitted over a medium like a wireless network. The processing chain finally comprises a decoder 14 that is adapted to decompress the encoded data and to provide a sequence of frames. The decoder 14 is adapted to implement a video decompression method according to the invention. In the following, the t^{th} frame of a decompressed sequence is denoted B_t .

Figure 2 shows the video compression algorithm carried out in the encoder 12. Figure 3 shows the following processed frames during the implementation of the compression algorithm. This algorithm of Figure 2, implemented by a processing unit like a DSP driven by an adapted software program, is repeated for each frame of the sequence of frames to be encoded. The steps shown in Figure 2 concern the encoding of frame I_{t+1} . It is assumed that the previous frame I_t has already been encoded and that the decompressed frame B_t corresponding to frame I_t is known.

Roughly, the method consists in two main stages. In a first stage 200, a first set of motion parameters is defined by using a forward approach to project segments of the previous frame I_t in order to predict the following frame I_{t+1} . Once projected, a predicted segmentation of the following frame I_{t+1} is provided. This segmentation is more likely to coincide with real objects of the following frame I_{t+1} than an arbitrary segmentation, a grid of blocks for example. Without considering the "holes" of the predicted segmentation as segments (they are not predicted by any part of the frame I_t), for each projected segment, a corresponding segment called a predicted segment is provided in the prediction, and above all, a set of motion parameters. In order to refine the prediction if necessary, a new motion

estimation is performed in a second stage 201, this time by using the backward approach on the predicted segments.

The first stage 200 is based on a forward approach, which means that segments of the previous frame I_t are searched in the following frame I_{t+1} . The compression method will now be disclosed in details.

At step 202, a segmentation of decompressed frame B_t is defined and stored. The segmentation of B_t consists in defining a subdivision of B_t into segments $S_{t,i}$. A set of segmentation parameters is determined. It defines the segmentation process that is implemented. Advantageously, the segment boundaries coincide with object boundaries in the frame B_t . Thus, the segments are "real" objects in the picture corresponding to frame B_t . In the following, all the segments $S_{t,i}$ are processed subsequently. Thus, a segment $S_{t,i}$ is considered in B_t at step 204.

At step 206, a corresponding segment $S_{t+1,i}^{\text{ref}}$ is searched in the following frame I_{t+1} to be encoded. The corresponding segment $S_{t+1,i}^{\text{ref}}$ is the segment of frame I_{t+1} which provides the best match with segment $S_{t,i}$ according to a given similarity measure. The similarity measures are known per se and will not be disclosed.

At step 208, some parameters that enable to retrieve $S_{t+1,i}^{\text{ref}}$ are stored. In particular a raw set of motion parameters $M_{t,i}^p$ is calculated. These motion parameters define the changes in the position of $S_{t+1,i}^{\text{ref}}$ with respect to $S_{t,i}$. For example, the set of motion parameters $M_{t,i}^p$ defines a translational motion. According to the forward approach, the predicted segment denoted $S_{t+1,i}^{\text{p,forward}}$ and the raw set of motion parameters $M_{t,i}^p$ are defined as follows :

$S_{t+1,i}^{\text{p,forward}} = \text{MC}(S_{t,i}, M_{t,i}^p)$, where $\text{MC}(S_{t,i}, M_{t,i}^p)$ is the motion compensation operation using $M_{t,i}^p$ as motion parameters ;

$$M_{t,i}^p = \arg \min_{\substack{M \text{ in motion} \\ \text{search range}}} (\text{diff}(\text{MC}(S_{t,i}, M), S_{t+1,i,M}^{\text{ref}})) \quad (\text{for example}) ;$$

where $S_{t+1,i,M}^{\text{ref}}$ is the segment of the following frame I_{t+1} that coincides with $\text{MC}(S_{t,i}^{\text{ref}}, M)$ and $\text{diff}(a,b)$ measures the similarity of a and b (the higher the measure, the less a and b are alike – it can be, for example, the sum of square differences of the pixel color values over the whole segment) ;

$S_{t+1,i}^{p,forward}$ is a raw predicted segment.

At this step, no processing is done to deal with overlapping between the different predicted segments $S_{t+1,i}^{p,forward}$. The overlapping issues are dealt with as disclosed below. Steps 202-208 are repeated until all the segments $S_{t,i}$ of previous decompressed frame B_t are considered. Thus, for each segment $S_{t,i}$, a corresponding predicted segment $S_{t+1,i}^{p,forward}$ is defined in the prediction together with a raw set of motion parameters $M_{t,i}^p$ called forward motion parameters.

Once every segment of the previous decompressed frame B_t is projected, some raw predicted segments may overlap each other. Some decisions is made at step 210 for solving the intersection between adjacent segments. Thus, overlapping parameters are calculated. According to a first embodiment, it is determined which segment is in front of which. How to make these decisions is not within the scope of the present invention. When it is done, predicted segments have their final shape, i.e. the original shape minus the possibly hidden parts. According to another embodiment, a merge parameter α is determined for each pair of adjacent segments. For each pixel of the intersection between the adjacent segments, a value of the pixel $P_{overlap}$ is defined by : $P_{overlap} = \alpha P_{segment1} + (1 - \alpha) P_{segment2}$, where $P_{segment1}$ and $P_{segment2}$ are the values of the corresponding overlapping pixels of both segments.

The prediction of the following frame I_{t+1} resulting from the set of predicted segments $S_{t+1,i}^{p,forward}$ may have holes. These holes correspond to newly uncovered parts of the following frame I_{t+1} . The holes are considered as new predicted segments or their contents are stored at step 212. Holes processing is not within the scope of the invention. In a possible embodiment, holes are added to the projected segmentation as new segments to be processed in the next step of the algorithm. They could also be merged with an existing predicted segment, or simply be stored as holes to be processed after motion processing was done. In any case, information regarding holes is encoded and stored. After step 212, a set of $S_{t+1,i}^{p,predicted}$ segments that corresponds to the set of $S_{t+1,i}^{p,forward}$ segments after having been processed for holes and overlapping is defined. At step 213, it is decided whether a calculation of a new best set of motion parameters by using a backward approach is necessary. If it is necessary, the second stage 201 is performed and a corresponding flag [YES] is memorized. If not, a corresponding flag [NO] is memorized and step 220 is directly performed for calculating residual frame R_{t+1} as will be disclosed below.

If necessary, a new motion estimation is performed in the second stage 201, by using a backward approach based on the predicted segments $S_{t+1,i}^{p,predicted}$. At step 214, a predicted segment $S_{t+1,i}^{p,predicted}$ as provided by the forward approach is considered. At step 216, a search is carried out in the previous frame B_t to find the segment of frame B_t denoted $S_{t,i}^{p,backward}$ that is the closest to the considered predicted segment $S_{t+1,i}^{p,predicted}$ according to the given similarity measure. At step 218, the new best set of motion parameters denoted $M_{t,i}^p + \Delta M_{t,i}^p$ is calculated. $\Delta M_{t,i}^p$ is a motion parameters correction such that $M_{t,i}^p + \Delta M_{t,i}^p$ defines the motion from $S_{t,i}^{p,backward}$ to $S_{t+1,i}^{p,predicted}$. The new best prediction for $S_{t,i}^{p,backward}$ is searched in a small area around the segment defined by applying the forward motion parameters $M_{t,i}^p$ to the predicted segment $S_{t+1,i}^{p,predicted}$. Steps 214-218 are repeated until all the predicted segments $S_{t+1,i}^{p,predicted}$ are considered. At this point, remaining holes are processed.

At step 220, a residual frame R_{t+1} is computed and encoded. The encoding method is not within the scope of this invention. In a possible embodiment, residual frame R_{t+1} may be encoded on a segment basis using the projected segmentation ($S_{t+1,i}^{p,predicted}$ and holes). The residual frame R_{t+1} defines the structural differences between the image prediction $B_{t+1}^{predicted}$ (the reunion of all predicted segments $S_{t+1,i}^{p,predicted}$ and processed holes) and the predicted image I_{t+1} . According to the invention, the best set of motion parameters $M_{t,i}^p + \Delta M_{t,i}^p$ is stored with a multi-layer motion description. The first layer contains the raw set of motion parameters $M_{t,i}^p$ and the flag [YES] or [NO] indicating if the decoder 14 should wait for an additional layer. The second layer contains the motion parameters correction $\Delta M_{t,i}^p$. At the end of the compression method, the compressed data provided by the encoder 12 are the segmentation parameters, the motion parameters $M_{t,i}^p$ or the best set of motion parameters $M_{t,i}^p + \Delta M_{t,i}^p$ of each segment contained in the multi-layer motion description, the overlapping information, the holes information and the residual frame R_{t+1} .

Upon reception of the compressed data, the decoder 14 applies the algorithm disclosed on Figure 4. Figure 5 shows the processed frames during the implementation of the decompression method. The same algorithm is repeated for each frame B_{t+1} to be decompressed. It is assumed that a previously decoded frame B_t is known and that the following frame B_{t+1} has to be decompressed.

At step 402, frame B_t is segmented based on the set of segmentation parameters by using the same algorithm and the same settings as its counter part B_t at the decoder side. These settings are set once and for all or are transmitted with encoded frames. The segments of B_t are denoted $S_{t,i}$ for clarity reason. A segment $S_{t,i}$ of B_t is considered at step 404 and the first layer motion parameters $M_{t,i}^p$ of segment $S_{t,i}$ are decoded and applied at step 406. A predicted segment $S_{t+1,i}^p$ is obtained. Steps 404-406 are carried out for all the segments of the decompressed frame B_t .

Overlapping parameters are decoded and applied at step 408 to segment $S_{t+1,i}^p$ to obtain a new segment denoted $S_{t+1,i}^{p,o}$. Since the reunion of the segments $S_{t+1,i}^{p,o}$ may not cover the all frame, the holes of B_{t+1} are predicted according to hole information contained in the compressed data, at step 410. Then, it is checked in step 412, if the flag contained in the first layer of the motion description indicates that additional motion information is contained in the second layer. If no additional motion information is contained in the compressed data, residual frame decoding is directly performed. A following predicted frame is defined by all the segments $S_{t+1,i}^{p,o}$. At this point, hole filling is performed, defining a predicted frame B_{t+1}^{pred} . Residual frame R_{t+1} is decoded and applied to the predicted frame B_{t+1}^{pred} to compute the final decoded frame B_{t+1} , at step 414.

If additional motion information is contained in the compressed data, at step 415 motion parameters correction $\Delta M_{t,i}^p$ is decoded and a corresponding improved segment $S_{t,i}^b$ is retrieved in the decoded frame B_t at step 416. This corresponding improved segment $S_{t,i}^b$ is the segment of B_t which would be projected on segment $S_{t+1,i}^{p,o}$ if the corrected motion parameters $M_{t,i}^p + \Delta M_{t,i}^p$ were applied to it. The corrected motion parameters $M_{t,i}^p + \Delta M_{t,i}^p$ are the raw set of motion parameters $M_{t,i}^p$ corrected by the motion parameters correction $\Delta M_{t,i}^p$. At step 417, the projection of $S_{t,i}^b$ using $M_{t,i}^p + \Delta M_{t,i}^p$ provides a corrected predicted segment $S_{t+1,i}^{p,o,c}$. A following corrected predicted frame is defined by all the segments $S_{t+1,i}^{p,o,c}$. At this point, hole filling is performed, defining a final corrected predicted frame B_{t+1}^{pred} . Then the residual frame R_{t+1} is decoded and applied to the final corrected predicted frame B_{t+1}^{pred} , at step 418 to provide the final decoded frame B_{t+1} .

Advantageously, according to a particular embodiment for a given segment, a motion vector is defined. This motion vector contains the first and second layers of the

motion description. The forward motion parameters are the integer part of this vector. The predicted segmentation $S_{t+1,i}^p$ is computed according to this truncated motion information contained in the vector by only considering the integer part.

For the backward motion correction of each predicted segment $S_{t+1,i}^{p,o}$, the full precision vector is used. In this case, there is only one actual layer of motion parameters : backward and forward motions are contained in one motion symbol. Still, the motion description is two-layered.

In the previous embodiment, calculation of overlapping parameters at step 210 and the corresponding step 408 are performed for a predicted frame B_{t+1} , after all the segments have been predicted. According to an alternative embodiment, overlapping parameters are calculated for each segment after step 208. Thus, they are calculated and encoded segment by segment. Accordingly, the overlapping parameters are applied segment by segment just after step 406 in the decompression method.

There are numerous ways of implementing functions by means of items of hardware or software, or both. In this respect, the drawings are very diagrammatic, and represent only possible embodiments of the invention. Thus, although a drawing shows different functions as different blocks, this by no means excludes that a single item of hardware or software carries out several functions. Nor does it exclude that an assembly of items of hardware or software or both carry out a function.

The remarks made herein before demonstrate that the detailed description, with reference to the drawings, illustrates rather than limits the invention. There are numerous alternatives, which fall within the scope of the appended claims. The words "comprising" or "comprise" do not exclude the presence of other elements or steps than those listed in a claim. The word "a" or "an" preceding an element or step does not exclude the presence of a plurality of such elements or steps.